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NEW MATERIALS

TRENDS IN OPTOELECTRONIC APPLICATIONS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Sep 85 pp 89-99

[Text] The optoelectronics industry including mass optical communication has grown to such an extent that it is now regarded as a pillar supporting today's highly advanced information society, and the industry is expected to expand further and further in the future.

The output of the optoelectronics industry that stood at ¥82.8 billion in 1980 amounted to ¥658.9 billion in 1984 for a hefty eightfold increase in 4 years, registering an average annual growth rate of 51.4 percent compared to 14.1 percent recorded by the electronics industry during the same period. The output of ¥658.9 billion is broken down into optoelectronic parts such as lasers and optical fibers which amounted to about ¥315 billion, optoelectronic devices such as optical input-output devices, laser-applied devices, optical transmission devices, and optical disks which totaled about ¥255 billion, and optoelectronic systems, such as those for optical communications, made a total of about ¥89 billion (see Figure 1).

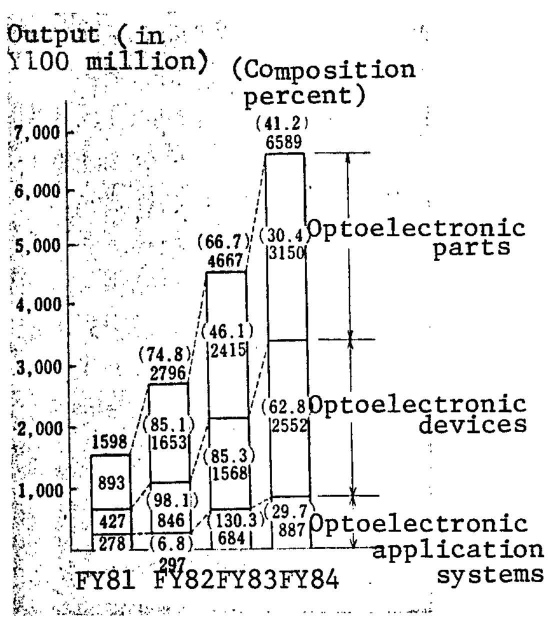

Figure 1. Yearly Transition of Output in Optoelectronics Industry

The optoelectronics industry's potential is so high that it is expected to advance beyond technological limitations which may be imposed on the electronics industry and continue growing at a pace higher than that achievable by the IC industry. Technologywise, the Japanese optoelectronics industry that has been gaining strength now shares the world-leading position with the United States.

In the optoelectronics industry, materials assume great importance. It may even be safe to say that what has been sustaining the industry's growth is material technology innovation. The optoelectronic materials include line materials, light source materials, light detection materials, and materials for optical modulation, optical deflection, optical display, and optical recording.

In this paper, the writer will first review the present status of the optoelectronics industry, the characteristics of optoelectronic technologies, and various optoelectronic parts. He will then discuss the technological features, production methods, materials, products, and marketability of optical fibers and semiconductor lasers which make up the core of optoelectronic technologies and also optical disks, which hold the key to the successful storage and management of information whose volume has been increasing, keeping pace with the advanced information society.

2. Optoelectronic Parts

The term "optoelectronics" is the combination of "optics" and "electronics." Optoelectronics therefore may be defined as a technological field where optics and electronics are merged.

The optoelectronic technologies use: 1) the high frequency of light as made use of for mass optical communication and optical information processing; 2) the ability of light to enable PCM modulation, PPM modulation, and intensity modulation by means of short optical wave pulses; 3) the rectilinearity and directivity of light; 4) the ability of light to be converged into a microspot for energy density enhancement; and 5) changes which can be caused in optical amplitude, phase, polarization plane, and frequency.

Optoelectronic parts are listed in Table 1. They are made of optoelectronic materials. With optoelectronics comprising a merged technological field, the optoelectronic materials range widely from inorganic materials (including both metals and nonmetals) to organic materials.

3. Optical Fibers

3.1. History and Features of Optical Fibers

Optical fiber research has been taking place for scores of years. In the early days, optical fibers were in use only for short-distance optical transmission. In 1966, Kao (working at the STL Laboratory of Britain) indicated that high-purity quartz glass enables the production of low-loss optical fibers. In 1970, he succeeded in recording a transmission loss of about

Table 1. Examples of Optoelectronic Devices

Function	Device
1. Light emission, display	Various lasers, light emitting diodes, light generators based on nonlinear optics, CRT's, plasma displays, liquid crystal displays, EL displays, etc.
2. Photoelectric conversion	Phototubes, photomultipliers, light receiving diodes, photoconductive devices, imaging devices, optical sensor arrays, etc.
3. Optical control	Electrooptic and acoustooptic devices, functional devices such as those for optical amplification, coupling, branching, filtration, isolation, switching and logic operation, optical integrated circuits, etc.
4. Optical transmission	Optical fibers and peripheral devices, etc.
5. Optical recording	Photosensitive materials, optical memory materials, etc.

20 dB/km with quartz-based optical fiber test-manufactured at Corning Glass Works. The subsequent progress of optical fiber production technology that went at an accelerating tempo led to realization in 1979 of a transmission loss in optical fiber of 0.2 dB/km at a wavelength of 1 μm.

The features of optical fibers made of glass include: 1) they are light weight, thin, and easily bendable; 2) they have large transmission capacity per unit cross-sectional area; 3) being insulators free of electromagnetic induction, they are highly resistant to external noise; 4) with their low transmission loss, they are usable on a wide wavelength band, and hence enable long transit spans. Furthermore, the optical fiber application range is quite extensive, since optical fibers are usable not only for optical communications but also for optical measurement and optical energy transmission.

3.2. Types of Optical Fiber, Their Structures

The basic structure of optical fiber is classified into three types according to the refractive index distribution and the fiber core size as shown in Figure 2. In the multimode step-index fiber, the lengths of paths taken by multiple light rays (multiple modes) propagating through the optical fiber, vary with the angles of incidence into the optical fiber of such light rays so that group velocity variation results. Such group velocity variation causes the waveforms of optical pulse propagation to be distorted and the transmission charactersitic to deteriorate. In the multimode graded-index fiber, the core refractive index decreases continuously with the radial distance from the core axis, and light rays are propagated while being

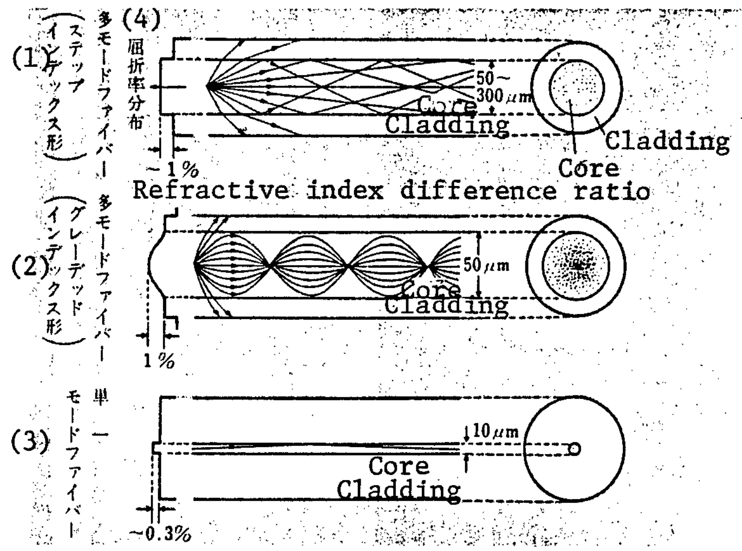

Figure 2. Representative Optical Fiber Structures and Ray Paths

Key:

1. Multimode step-index fiber
2. Multimode graded-index fiber
3. Single-mode fiber
4. Refractive index distribution

periodically converged toward the core axis because of the converging action of the core. In the multimode graded-index fiber, even though the paths taken by light rays more deviated from the core axis are longer since the speed of light traveling through a propagation medium is inversely proportional to the refractive index, the group velocity of different light rays becomes approximately equal so that intermodal dispersion is kept small.

In the single mode fiber, the core diameter is very small, about 10 μm, so that light rays following only one optical path are propagated, whereas those which take other optical paths are cut off. The single mode fiber is therefore suitable for broad-band transmission.

3.3. Optical Fiber Materials

The materials known to be suited to make optical fibers are glasses and plastics. The glasses used to make long-wavelength optical fibers are broadly classified into the fused quartz family and the compound glass family.

The fused-quartz optical fiber is composed of SiO_2 (silica), that is the main component, and a small amount of dopants added as required to control the refractive index. The commonly used dopants include GeO_2, P_2O_5, and B_2O_3 which, like SiO_2, make up the glass network, the oxides of ions (such as Ga, In, Mg, Ca, Li, and Na) which modify the glass network, and oxides (such as TiO_2, Sn_2O, and Al_2O_3) coming between the former two groups. Negative ions such as F can also be used as dopants.

The compound-glass optical fibers include alkaline borosilicate ($R_2O-B_2O_3-SiO_2$) fibers, soda lime silicate ($R_2O-CaO-SiO_2$) fibers, and alkali lead silicate ($R_2O-PbO-SiO_2$) fibers; these fibers also contain trace amounts of many other kinds of ingredients.

Plastic optical fibers comprise cores and claddings made of plastics such as polymethamethylacrylate (PMMA) and polystyrene (PS).

3.4. Optical Fiber Production Method

A fused-quartz optical fiber production system comprises, broadly classified, three processes; optical fiber preform production, drawing, and coating. The coated optical fiber turned out via the three processes easily flaws, and its mechanical strength is small; so that it is further covered with plastic cladding by the extrusion molding method. Scores of such plastic-clad optical fibers are bundled into units; and units are incorporated into a cable structure for practical applications.

Of the foregoing optical fiber production processes, it is the preform production process that most affects the optical fiber quality and properties. There are three methods used to produce preform; the outside chemical vapor deposition (CVD) method developed by the Corning Glass Works, the modified chemical vapor deposition (MCVD) method that is an improvement on the CVD method, and the vapor phase axial deposition (VAD) method developed by Nippon Telegraph and Telephone Corp.'s (NTT's) Ibaraki Telecommunication Laboratory. The VAD method is the first continuous preform production process ever developed. Besides being suitable for mass production, the preform produced by the method excels that produced by the MCVD method in terms of loss characteristic; hence it is at present the most widely used method for optical fiber production.

3.5. Optical Fiber Makers and Markets

Fused-quartz optical fibers account for 90 percent of the total optical fiber market. In Japan, the top three makers of fused-quartz optical fibers--that is, Sumitomo Electric Industries, Ltd., Furukawa Electric Co., Ltd., and Fujikura Ltd.--hold a total market share of 80 percent with the remaining portion of the market being shared by such makers as Hitachi Cable, Ltd., Dainichi-Nippon Cables, Ltd., and Showa Electric Wire & Cable Co., Ltd. The market for plastic optical fibers is monopolized by Mitsubishi Rayon Co., Ltd. (see Table 2).

For fiscal 1983, Sumitomo Electric Industries is estimated to have output ¥18 billion worth of optical fibers and related products. Furukawa Electric also manufactured ¥13 billion worth of similar products; and Fujikura ¥12 billion. In that fiscal year, the domestic optical fiber sales increased as much as 120 percent from the previous fiscal year to total ¥52 billion. Such a large increase in optical fiber sales recorded for fiscal 1983 was attributable to NTT's purchase of a large quantity of optical fibers for long-distance applications needed in constructing its information network system (INS) to cover the entire main island of Japan. In fiscal

Table 2. Principal Optical Fiber Makers

Country	Maker	Share (percent)	Fiber type	Production method
Japan	Sumitomo Electric Industries	32	Fused-quartz fiber	Modified CVD, VAD
	Furukawa Electric	28	"	"
	Fujikura Ltd.	20	"	"
	Hitachi Cable	12	"	Soot accumulation method
	Dainichi-Nippon Cables	4	"	Rod-in-tube method
	Showa Electric Wire & Cable	4	Compound glass fiber	Double crucible method
	Nippon Sheet Glass	0	"	"
	Mitsubishi Rayon	0	MMA	Plastic drawing method
United States	Corning		Fused-quartz fiber	Modified CVD, outside CVD
	ITT		"	"
	Western Electronic		"	"
	Palteck		"	Modified CVD, plasma CVD
Europe	GEC (United Kingdom)		"	Modified CVD
	STL (United Kingdom)		"	"
	Telefunken (West Germany)		"	"
	Philips (Holland)		"	Plasma CVD
	Pireri (Italy)		"	(Corning's technology)

1984, without such an extraordinary large-volume purchase, the optical fiber output amounted to ¥63 billion (up 21 percent from the previous year) according to an estimate made by the Optoelectronic Industry and Technology Development Association (OITDA). OITDA, anticipating that the future expansion of subscriber-line public communication systems will generate more demand for optical fibers, expects that the market for optical fibers and related products will grow to ¥90 billion by fiscal 1988. The prerequisite conditions for OITDA's forecast to come true are a substantial growth in the output of optical fiber cables for subscriber lines and a significant drop in optical fiber prices.

To make lower-priced optical fibers available, NTT and different electric wire makers are in the process of developing optical fibers for ultralong wavelength applications (infrared fibers) which will realize transmission losses at least four orders of magnitude smaller than those in the fused-quartz optical fibers presently in use (see Table 3).

Table 3. Optical Fibers Being Developed

Type	Composition	Minimum transmission loss achieved
Heavy metal oxide glass	GeO_2-sb_2O_3 TiO_2-ZnO-BaO	5 dB/km (2 μm)
Fluoride glass	ZrF_4-BaF_2-Ga_3 ZrF_4-BaF_2-LaF_3	12 dB/km (2.55 μm)
Chalcogen glass	As-S As-Ge-Se As-Se As-Ge-Se-Te	64 dB/km (2.55 μm)
Metal halogenide crystal	KRS-5(TIBr-TII) CsBr AgBr-AgCl KCl	220 dB/km (10.6 μm)

The development of low transmission loss plastic optical fibers is also being actively promoted, for example, by Mitsubishi Rayon; the company achieved a transmission loss of 20 dB/km with test-manufactured plastic fibers.

4. Semiconductor Lasers

4.1. History and Characteristics of Semiconductor Lasers

In 1962, three U.S. firms, GE, IBM, and MIT, successively succeeded in oscillating semiconductor lasers made of gallium arsenide (GaAs). In 1970 Dr Iwao Hayashi, working at Bell Laboratories at that time, successfully developed a double heterojunction laser (DH laser) to enable continuous laser oscillation at room temperature.

Compared with gas lasers, semiconductor lasers have the following advantages: 1) they are small with laser devices themselves measuring only about several hundred microns in diameter; 2) their electricity requirement is small, and they can produce more than several milliwatts of optical output from about 2 V/100 mA of input; 3) they enable laser optical intensity modulation at about 1 GHz by means of directly modulating the applied current; 4) they enable a wide range of emission wavelengths from visible rays to infrared rays to be obtained by selecting appropriate semiconductor materials (by

appropriately changing the composition proportions among two or more elements); 5) they are scores of times to several hundred times cheaper than gas lasers of equivalent output capacity.

On the strength of the foregoing advantages, semiconductor lasers are finding extensive use as light sources for optical communications and optical information processing; they are used, for example, for compact disks, video disks, optical files, and laser printers.

4.2. Types of Semiconductor Lasers, Their Structures

The structures of semiconductor lasers are basically very simple; they are pn junction diodes. When a current is made to flow through a pn junction diode in the forward direction, laser oscillation occurs. Such laser oscillation does not occur even if a current is made to flow through an ordinary diode. Laser oscillation to take place requires the energy that is emitted when minority carriers injected into the laser diode are recombined to be efficiently converted into light. To meet the requirement, it is generally required that the region where recombination takes place (that is, the region near the pn junction called the active region) be made of material of direct transition type.

Semiconductor lasers can be divided into two categories by oscillation wavelength; those to oscillate on a short wavelength band (0.7 to 0.8 μm) and those to oscillate on a long wavelength band (1.2 to 1.6 μm). The former category includes GaAlAs/GaAs semiconductor lasers used for such applications as optical disks and short-distance optical communications; the latter category includes GaInAsP/InP semiconductor lasers used for long-distance optical communications.

4.3. Semiconductor Laser Applications

Figure 3 shows principal semiconductor laser applications for different oscillation wavelengths.

Short-wavelength semiconductor lasers are mostly used for compact disks. Recently, with semiconductor lasers capable of producing an output power of over 10 milliwatts now available, semiconductor lasers are more popular than gas lasers. In fact, demand for semiconductor lasers to be used as light sources for additionally-writable (DRAW type; direct read after write type) optical disks and laser printers had been rising. Furthermore, there is a highly potential demand for high-output semiconductor lasers to be used as light sources for recording and reading on erasable and rewritable optical disks which are now in the process of development, and different makers have been introducing short-wavelength high-output lasers one after the other. Such high-output semiconductor lasers are, however, priced one order of magnitude higher than the conventional semiconductor lasers. The lifetime of high-output semiconductor lasers is shortened by the heat generated when they are used for high-output operation.

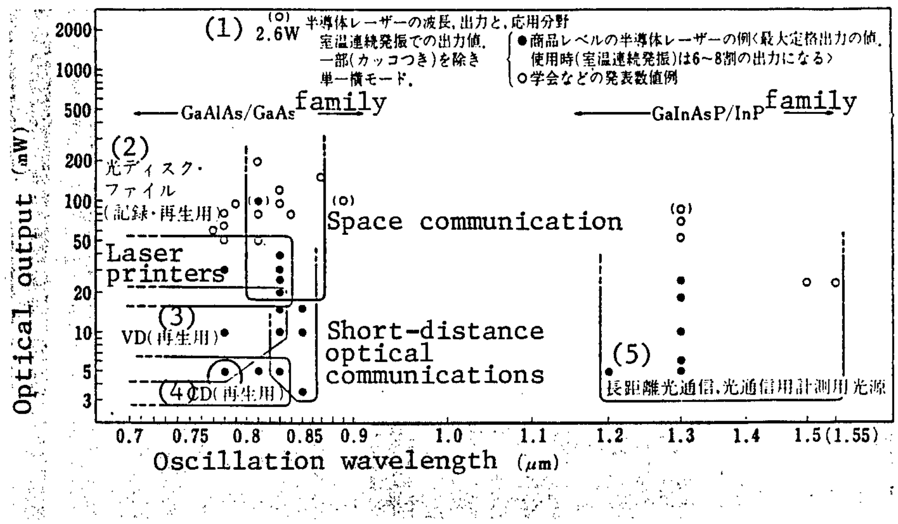

Figure 3. Wavelengths, Optical Output and Applications of Semiconductor Lasers

Each unpainted circle (o) indicates the optical output level of a prototype semiconductor laser; each painted circle (●) indicates the maximum rated optical output of a commercialized semiconductor laser. Application boundary lines are only for approximate delimitation.

Key: (o) Semiconductor laser wavelength, output, and application field

2.6 w Output by continuous oscillation at room temperature. For single transverse mode, except parenthesized circles.

● Semiconductor laser already commercialized (Maximum rated output is indicated; output in operation (during continuous oscillation at room temperature) is 60-80 percent of the maximum rated output.)

o Data, for example, disclosed at a meeting of an academic society

2. Optical disk files (for recording and reproduction)
3. Video disks (for reproduction)
4. Compact disks (for reproduction)
5. Long-distance optical communications, and light sources for optical communication measurement

Long-wavelength semiconductor lasers are mostly used as light sources for optical communications. Generally, semiconductor lasers are designed to oscillate at wavelengths at which the transmission loss in fused-quartz fiber is small. At present, most semiconductor lasers have an oscillation wavelength of 1.3 μm, but R&D studies are underway to develop semiconductor lasers with an oscillation wavelength of 1.55 μm at which the transmission loss in fused-quartz fiber is smaller (see Table 4). In many cases when high-speed direct modulation is made on the 1.55-μm band, oscillations of up to about 10 axial modes take place reflecting a transient state of laser operation. Hence, the semiconductor devices on which R&D work is being positively promoted include: 1) distributed feedback (DFB) and distributed Bragg reflection (DBR) semiconductor lasers using a resonator which has a

Table 4. Examples of Already Test-Manufactured or Announced High-Output Semiconductor Lasers

Maker	Anritsu Electric	Oki Electric Industry	NEC Corp.	NEC Corp.	NGG	Mitsubishi Electric
Structure	BH*1	VIPS	DC-PBH	DFB-DC-PBH*2	PM-DBM	PBC
Crystal growth method	LPE	LPE	LPE	LPE	LPE	LPE
Oscillation wavelength (μm)	1.3	1.3	1.3	1.3	1.32	1.3
Output (mW) by continuous oscillation of fundamental transverse mode at room temperature	79 (multi-mode)	65	70	55	51	About 70*3
Threshold current (mA)	60	About 15	15-30	32-40	20	10
Optical beam divergence angle (degrees)						
oParallel with junction ($\theta_{\parallel}$)	20	30	22	About 30	--	25
oPerpendicular to junction ($\theta_{\perp}$)	30	30	35	About 40	--	30
Reliability (ascertained lifetime)	30°C	70°C	50°C	50°C	70°C	70°C
	5 mW	5 mW	20 mW	5 mW	150 mA	5 mW
	7,000 hours	4,000 hours	6,000 hours	3,000 hours	400 hours	3,000 hours
Output enhancement provision						
oBuried structure	Yes	Yes	Yes	Yes	Yes	Yes
oInternal current strangulation layer	Yes	Yes	Yes	Yes	Yes	Yes
oEnd-face asymmetric coating			Yes	*4		Yes
Remarks	Already commer-cialized (APL1300)			King between 45 and 50 mW output		Attached to heat sink with junc-tion up

Notes: 1. Semiconductor lasers of similar structure with 1.5 μm wavelength and 25 mW output already announced.
2. Semiconductor laser of similar structure with 1.55 μm wavelength and 23 mW output already announced.
3. Maximum output is 85 mW.
4. Front-face coating for reflection prevention only.

periodical feedback structure to enable wavelength selection; 2) C^3 semiconductor lasers using the wavelength selection capability of a complex resonator; and 3) semiconductor lasers which operate based on optical injection synchronization.

4.4. Semiconductor Laser Materials and Production Methods

The semiconductor laser substrate materials presently in use are GaAs single crystal and InP single crystal.

GaAs single crystal is produced either by the boat-grown method with the HB method being a typical one or by the LEC method (liquid-sealed pulling method).

To produce an epitaxial layer on a GaAs substrate, the vapor phase epitaxy (VPE) method or liquid phase epitaxy (LPE) method is used. The production processes that cover epitaxial growth through final inspection are considerably manual work-oriented. In the future, the introduction of mass-production processes using such methods as the molecular beam epitaxy (MBE) method and the organometallic chemical vapor deposition (MOCVD) method will be promoted. Compound semiconductors are much more difficult to handle than silicon. Whether compound semiconductor technology can be innovated, largely depends on the future advancement of material processing technology, particularly epitaxy technology.

The oscillation wavelength of a semiconductor laser is determined by its bandwidth. Figure 4 shows the correspondence between electronic materials and laser wavelengths. The underlined materials are those which cannot be made pn junction lasers; they, however, permit electron beam pumping and optical pumping. The semiconductor laser materials that can be obtained with relative ease at present include the GaAlAs and InGaAsP families. Such materials as CdS and PbSnTe, to be made obtainable, require the use of a large laser system.

4.5. Semiconductor Laser Market and Technological Trend

In the field related to visible-band semiconductor lasers, the output of compact disk (a kind of optical disk) players has started steadily growing with their prices dropping and with the menu of compact disks on sale expanding to offer an increasing variety of recordings (the industry anticipates that the compact disk player output will reach 2 million units this fiscal year). Sharp Corp., whose output of semiconductor lasers accounts for about 75 percent of the total semiconductor laser production in Japan, estimates that the total semiconductor laser production in Japan will reach about 3.2 million devices this fiscal year (up 30 percent from the previous fiscal year) and 6 million devices the following fiscal year (see Figure 5). The semiconductor laser market in Japan is projected to grow to ¥100 billion in 5 to 6 years. The leading maker, Sharp Corp., is followed by Mitsubishi Electric Corp. and Matsushita, which are ranked second and third, respectively, in semiconductor laser production and are engaged in cutthroat competition with each other in both semiconductor laser sales and development.

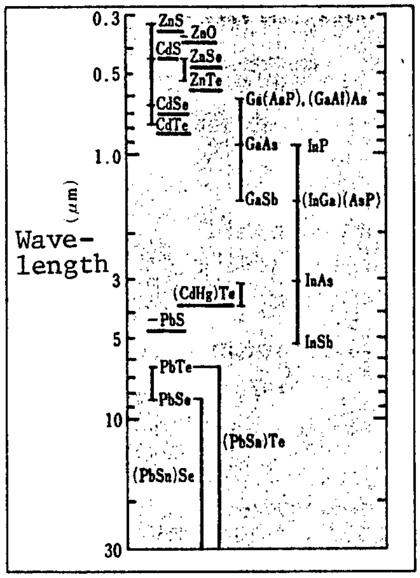

Figure 4. Semiconductor Materials and Laser Wavelength Ranges

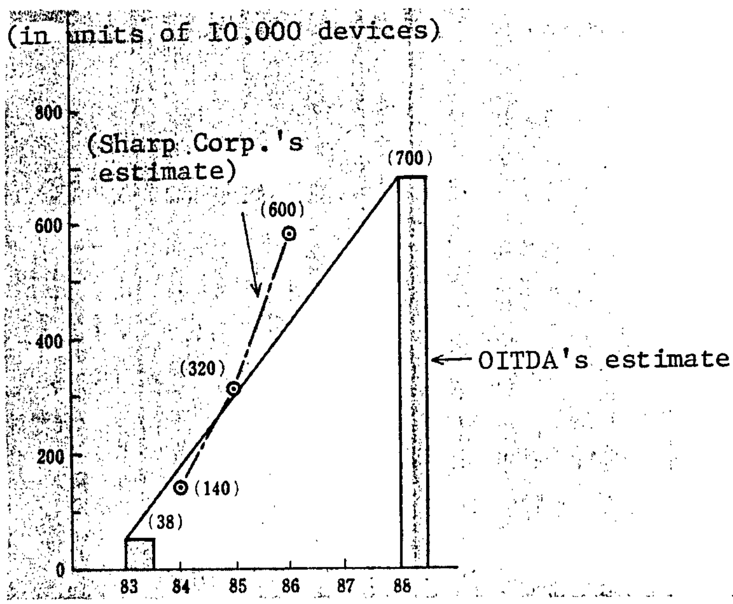

Figure 5. Transition of Short-Wavelength Semiconductor Laser Output in Japan

Recently, there is a trend in the semiconductor laser R&D work to give priority to R&D objectives. Depending on the intended application, priority in semiconductor laser R&D may be given to output power boosting, wavelength shortening, price lowering, reliability enhancement, mode stabilization or noise resistance enhancement. In regard to wavelength shortening, NEC Corp. test-manufactured a semiconductor laser capable of continuous oscillation at a wavelength of 0.67 μm at room temperature in February this year.

The element structures of semiconductor lasers have been growing more and more complicated in the course of their output and reliability enhancement. As the semiconductor laser structure becomes more complicated, it becomes more difficult to mass produce such semiconductor lasers. Eventually it becomes more difficult to make them as easy to handle and reliable as other general electronic parts. Thus, there are still many problems to be solved in the improvement of semiconductor lasers.

According to a forecast made by the conference on future compound semiconductors, the domestic market for such semiconductor laser substrate materials as GaAs and InP is going to expand at an annual rate of 40 percent, whereas the total semiconductor laser shipment in Japan is projected to increase from ¥10 billion in fiscal 1983 to ¥100 billion by fiscal 1990. By device, of the ¥10 billion worth of semiconductor lasers estimated to have been shipped in fiscal 1983, about 80 percent was estimated to have been accounted for by optical devices (such as LED's and semiconductor lasers), with the remaining 20 percent or so comprising high-speed devices. According to a forecast made by Sumitomo Electric Industries, Ltd., the global market for the III-V group of compound semiconductor devices will be worth about ¥1.6 trillion in 1990, with Japanese makers holding a 47-percent market share. The company predicts that about 20 percent of the domestic market will be accounted for in optical devices.

In the Japanese GaAs market, at present, 10 makers are engaged in competition to develop GaAs substrates with lower dislocation density. They are Sumitomo Electric Industries, Mitsubishi Monsanto Chemical, Hitachi Cable, and Mitsubishi Chemical which started GaAs development and mass production earlier than others; Dowa Mining, Sumitomo Metal Mining, Showa Denko, Furukawa Co., and Iwaki Semiconductors which joined the four forerunners in 1982; and Nippon Mining which entered the market in 1983 (see Table 5).

5. Optical Disks

5.1. Characteristics of Optical Disks

Whereas the amount of information handled in society has been increasing, keeping pace with the advancement of information processing techniques, the optical disks have been attracting attention as a means of mass information storage.

To read the information recorded on an optical disk, an optical beam emitted by a laser is converged on the information-recorded surface of the optical disk, and changes in the quantity of reflected light are detected as signals. The optical beam spot formed on the optical disk surface measures 1-2 μm in diameter. Compared with the conventional types of memory, the optical disk has the following features (see Table 6):

1) Its recording density is very high; scores of times to several hundred times higher than that on magnetic memory. An optical disk with a diameter of 12 cm, for example, can store 550M bytes of information; if the diameter is increased to 30 cm, as much as several gigabytes of information can be stored on the optical disk.

Table 5. Status of GaAs Single-Crystal Makers

Maker	Semiconductor substrate (* = in the process of development) GaAs Sub-strate	GaAs Epi-taxial	InP	GaP	GaAs production method	Estimated Ga consumption (kg/month)	Present status and future plan
Sumitomo Electric Industries	Yes	Yes	Yes	Yes	3T-HB HP-LEC	300-350	The world's top maker of GaAs having 200 users in 20 countries. The firm built the world's largest-scale compound semiconductor plant in 1978, and is now constructing a new larger plant.
Mitsubishi Monsanto	Yes	Yes		Yes	GF HP-LEC	250-300	The world's top maker of GaAs P epitaxial wafers for LED's. As for the GaAs wafers for FET's and IC's, the firm is expediting quality improvement with the aid of Mitsubishi Chemical Industries. The firm aims at bringing the ratio between its sales of GaAs wafers for LED's and those of GaAs wafers for other devices to 50:50 by 1985. (The present ratio between them is 70:30.)
Mitsubishi Metal	Yes	*	Yes		LEC	50-100	The firm aims at becoming an integrated GaAs maker which produces not only GaAs wafers as base material but also other peripheral materials and intermediate devices readily usable for system structuring.
Hitachi Cable	Yes	Yes	Yes		GF HP-LEC	100-120	The firm has been engaged in GaAs research and development for about 10 years. It is good at large substrates (boat grown) with low dislocation density and undoped semi-insulating substrates (LEC). The firm holds a top market share for low dislocation density wafers for LED's.
Sumitomo Metal Mining	Yes		I	Yes	HP-LEC	500-600 (including Ga sold by the firm)	The firm applies its technological asset it accumulated as a supplier of Ge, GaP, LN, and GGG to GaAs production.

[Continued]

[Continuation of Table 5]

Showa Denko	Yes	Yes	Yes	Yes	HP-LEC	30-40	The firm finished R&D work on InP commissioned by Japan Electronic Industry Development Association, and is now promoting the diversification of its products using its high-purity polycrystal technology and dislocation reduction technology. The firm is also expediting the development of GaAs epitaxial wafers for both infrared LED's and other devices rather than LED's using its LEC technology.
Iwaki Handotai (Shin-Etsu Handotai)	Yes	Yes	Yes	Yes	LEC	100-150	Firm started test production of GaAs in October 1983, and is now shipping samples. It started mass production of GaAs substrates for IC's by applying the hardware and software technologies it has so far acquired. It will start shipping InP samples this year. GaAs polycrystal is to be supplied by Furukawa Elastic. Furthermore, the firm plans to start mass production of epitaxial wafers for LED's this fall.
Furukawa	Yes		*		HP-LEC	For use in R&D	Firm had started GaAs R&D focusing on wafers for IC's. Having started sample shipment of 3-inch wafers, the firm is now more confident of its technology. It plans to increase its crystal pulling capacity threefold (presently operating three sets of pulling equipment) by this fall to catch up all at once with those ahead of it.
Dowa Mining	Yes				HP-LEC	300-400 (including Ga sold by the firm)	Taking advantage of its position as a raw material supplier, the firm is engaged in large-scale R&D on substrates for IC's, and is producing substrates for discrete semiconductor devices. It has already started R&D on InP, InSb and epitaxial wafers.
Nippon Mining	*		Yes			For use in R&D	Firm is engaged in R&D centering on InP. It has a great advantage of self-supplying high-purity indium. The first has also started GaAs developments and is already shipping samples.

Note: HB = Horizontal Bridgman technique; GF = Gradual freeze method; HP-LEC = High-pressure pulling method.

Table 6. Comparison Among Different Types of Memory Devices

Memory type	Examples	Medium size (Diameter in cm)	Recording capacity (user area size in megabytes)	Data transfer rate (kilobytes/s)	Average access time (ms)	Medium replaceability
Optical disks (reference data for comparison)	CD-ROM (for reproduction only)	12	550/single side	250	About 1.5 s	Yes
	Hitachi H-6975 (direct read after write type)	30	1310/single side	1500*3	About 300	Yes
Optomagnetic recorders	Hitachi's prototype	12	550/double sides	440	About 100	Yes
	Sony's prototype	30	1050/single side	360	100-133	Yes
Magnetic disks	Compact Winchester	13.3	20/4 sides	625	About 90	No
	IBM3380	35.6	2600/spindle*1	3000	About 24	No
	5.25-inch standard	13.3	0.65-1.3/double sides*2	31-63	About 270	Yes
Floppy disks	High recording density type	13.3	4.2-5.3/double sides*2	375	About 160	Yes
	3.5-inch standard	8.9	0.5*2	31.3/62.5	365/180	Yes
	Vertical prototype	13.3	34	625	-	Yes
Magnetic tape	IBM3420-8	27	165	1250	Several tens of seconds	Yes
	IBM3480 (cartridge)	10x12.5x 2.5	200	3000	Several tens of seconds	Yes
Magnetic bubble memory	1M bit memory	-	1M bits/device	100	12.5	Yes

Notes: 1. Each spindle consists of 9 disks with 16 sides usable. Each machine has 2 spindles.
2. Unformated capacity.
3. 440 kilobytes/s for driving section.

2) Unlike other information storage media such as the magnetic disk that causes the magnetic head to be worn and the record to be worn while in use, the optical disk causes neither itself nor the information sensor to be worn; since it enables information to be recorded on or reproduced from it without requiring direct contact between it and the sensor.

3) Like the record, the optical disk can easily be mass-produced by pressing, using a master pattern.

4) The optical disk enables data transfer at a rate of 10^2 to 10^3K bits/s.

Its access time is about 0.5 second, to be, at least, comparable to that of the floppy disk.

The optical disk also features a low production cost per bit and a low bit error rate. Since, as discussed in the foregoing, the optical disk has many advantages over the conventional types of information storage media; its makers are actively promoting research work on it, and the demand for it has been rising in such fields as compact disks and video disks for civil use, and document files and information memories for industrial use.

5.2. Types and Applications of Optical Disks

In an optical disk system in operation; a laser beam is converged on the information-recorded surface of an optical disk, changes in the intensity of light rays reflected from the optical disk are detected by a photodetector, and the detected optical intensity changes are converted into electrical signals.

The optical disk is broadly classified into three types by application (see Table 7).

Table 7. Different Types of Optical Disks

Type	Principal applications
ROM	Optical video disks Compact disks
DRAW	Color image files Document files Code information files
R/WM	Document files Image files Code information files Recordable compact disks

ROM: Read only memory
DRAW: Direct read after write (Also called write once type)
R/WM: Read write memory (Also called EDRAW = erasable DRAW)

1) A reproduction-only (ROM) optical disk stores information as irregularly shaped pits in it. To read the information stored on such an optical disk; the pits formed in it are scanned with a laser beam, the changes in the intensity of reflected light caused as a result of interference between the incident rays and reflected rays are detected by a photodetector, and the detected changes in the optical intensity are converted into electrical signals. The applications of this type of optical disk include video disks and compact disks.

2) An additionally-recordable (DRAW type) optical disk has only track address guide grooves and pits, unless additional information is recorded on it. To record additional information on such an optical disk, either pits are generated in it or the reflectivity of its information recording part is changed according to the contents of the additional information. It enables additional information to be recorded on it only once. The applications of this type of optical disk include document files and recording memories.

3) An erasable and rewritable (R/WM type) optical disk has guide grooves and track address pits like those found on the DRAW-type optical disk. Broadly classified, there are two methods usable to record information on this type of optical disk. In one of the two methods, optomagnetic recording is made using a thermomagnetic effect. For recording, the magnetic field, where information is to be recorded, is scanned with a laser beam so as to change the direction of the magnetic field. For reproduction, the angle of rotation (the magnitude of the Kerr effect) of the reflected laser beam's plane of polarization in the magnetized portion of space is measured. In the other method, reflectivity changes caused by crystal-amorphous phase transition are detected.

5.3. Optical Disk Materials

The materials used for information recording on optical disks differ among different types of optical disks (reproduction-only optical disks, DRAW-type optical disks, and erasable/rewritable optical disks) (see Table 8).

For recording on reproduction-only optical disks, photoresists are used (material for the master pattern). The master pattern made of photoresist is used to produce a permanent mold (metal mold). The surface pattern of the metal mold copied from the master pattern is pressed on acrylic-resin substrate blanks. The pressed acrylic-resin substrate disks then have metallic material deposited over them by evaporation.

For DRAW-type optical disks, ultraviolet-cureable resin, whose main component is Te, is mainly used as recording material.

The well-known recording materials used for erasable and rewritable optical disks include magnetooptic thin film such as TbFe, and crystal-amorphous TeOx whose phase transition is made use of.

Generally, for use of optical disks in the audio field, polycarbonate (PC) or PMMA is used as the substrate material; for use of optical disks as document

Table 8. Principal Optical Memory Materials

Classification	Material	Recording process	Recording mode	Sensitivity (mJ/cm^2)	Resolution (1/mm)	Detection method
Reproduction only (for mass copying)	Photoresist (master patterns of video and audio disks)	Photochemical reaction	Optical	$1-10^2$	3,000	Refractive index changes
Direct read after write type (DRAW)	Metallic thin film (Te, Bi, Au)	Fusion and removal	Thermal	Up to 10	Up to 1,500	Permeability and reflectivity changes
	Coloring matter (anthraquinone pigment)	Thermal diffusion	"	10	1,500	"
	Nitrocellulose pigment dispersing element	Sublimation	"	10	Up to 1,000	"
	Silver + polymer	Fusion and removal	"	Up to 5	1,000	Reflectivity changes
	Polymer + pigment group	Decomposition reaction	"	10^2	1,500	Permeability and reflectivity changes
	Amorphous thin film (AsTe)	Phase transition	"	10	1,000	"
Erasable type	Thermoplastic (Thermoplastic + PVK)	Deformation (relief)	Optical	10^{-1}	2,000	Refractive index
Rewritable type (additionally writable)	Magnetooptic thin film (TbFe, etc.)	Magnetization	Thermal	10^2	<2,000	Refractive index changes
	Amorphous thin film (TeOx)	Structural changes	Thermal	10	1,000	Reflectivity changes
	Polymer with additive coloring matter (retiren origome)	Thermal changes	"	10^2	Up to 1,000	"
	Photochromics (spiropirane group)	Isomerization	Optical	$1-10^2$	2,000	Permeability and reflectivity

files or record memories, PMMA or tempered glass is used as the substrate material.

5.4. Optical Disk Systems Being Marketed

The optical disk systems that are found on the market are broadly classified into two categories; one which comprises digital audio players (video disk players and compact disk players), and the other that includes document files and external record memories.

Pioneer Electronics Corp.'s "picture-showing records" may be representative of video disk players. Today, they are selling more for applications in the field of education or the entertainment business (backup music players, TV game machines, etc.), than for general civil use.

Compact disk players are manufactured by most of the Japanese audio equipment makers; perhaps due to the fact that the industry standardized the specifications in the early stage. Since the products are marketed by many makers, sales competition among them is quite severe.

The industrial-use optical disk systems comprise DRAW-type document files and record memories. The first Japanese firm to have commercialized document file systems is Toshiba Corp. which introduced its "Tosfiles" in 1982. It now holds a majority share of the market for document file systems in Japan. Ranked second and third in the market are Hitachi Ltd. and Matsushita Denso. Table 9 outlines the DRAW-type optical disks produced by different Japanese makers. Optical disks feature a high recording density, one to two orders of magnitude higher than those on other sorts of information-recording media. An optical disk with a diameter of 30 cm, for example, can store as much as several gigabytes of information which is equivalent in volume to information written on 15,000 to 60,000 A4-size sheets of paper.

The optical disks designed for use as external memory devices for computers have been collecting attention. Such optical disks must permit information to be erased and rewritten. Computer makers are positively conducting R&D on such optical disks. Hitachi Ltd., Sony Corp., and KDD (Kokusai Denshin Denwa Co.), for example, are promoting studies on optical disks which use an optomagnetic effect, whereas Matsushita Electric Industrial Co. and ECS of the United States are jointly working to develop optical disks which operate by making use of crystal-amorphous phase transition.

5.5. Optical Disk System Market

Table 10 lists industry's production forecasts on compact disk players, video disk players, software for such players, optical file systems, and optical disks.

The output of compact disk players that totaled 770,000 units in fiscal 1984 for a 3.3-fold increase from the previous fiscal year is estimated to increase 2.6 times in fiscal 1985, to reach 2 million units. The compact disk player production plans of seven major Japanese makers are listed in Table 11. As

Table 9. Outline of Different Makes of DRAW Type Optical Disks

(Based on the results of querying the makers)

Maker	Disk type	Disk: Diameter (cm)	Disk: rpm	Disk: Material	Recording film	Film formation method	Production start	Output (month)	Factory	Price (¥10,000)
Matsushita Denso	Optical	20	900	PMMA	Inorganic	Vacuum evaporation	May 1983	1,000	Okayama	3
Sanyo Denki Tokki	"	30	690	PMMA	"	--	- 1983	100	Gifu	Double-sided; 8.5 Single-sided; 5.5
NEC Corp.	"	30	900	PMMA	"	Vacuum evaporation	March 1983	-	Fuchu	6
Fujitsu Ltd.	"	30	900	PMMA	Inorganic	"	July 1985	OEM	-	6
Hitachi Maxell	"	30/13	600	Glass	"	"	May 1984	1,000	Tsukuba	Double sided; 7 Single sided; 5
Mitsubishi Electric	"	20	900	PMMA	Inorganic	"	-	OEM	-	3.2
Pioneer Electronic	"	20	450	PMMA	Organic pigment	Spin coating	1985	Undecided	Undecided	Undecided
Ricoh Corp.	"	20	450	PMMA	"	"	Undecided	Undecided	Undecided	2.5
Canon Inc.	"	20/13	Up to 1,800	Glass/ PMMA	Inorganic	Vacuum evaporation	October 1985	-	-	-
Sony Corp.	"	13/20/30	900-1,800	PC	"	Sputtering	January 1985	-	-	13¢; undecided, 20¢; 4.6, 30¢; 7.0
Toshiba Corp.	"	30	-	PMMA	"	"	January 1982	3,000	Yanagimachi	8.8
TDK Corp.	"	12-20	-	PMMA	Organic pigment	Spin coating	June 1986	100,000/year	Saku No 2 T.C.	0.5 or less
Daicel Chemical Industries	"	12-30	Up to 3,600	PMMA/CP	Inorganic	Vacuum evaporation	October 1985	500,000/year	Harima	Undecided
Mitsui Toatsu Chemicals	"	12	900	PMMA	Organic pigment	Application	1986	100,000/year	-	0.3
Matsushita Electric Industrial	"	20	-	PMMA			November 1984		Ibaraki	4.0

Table 10. Market Forecast for Optical Disk Systems and Software

Classification		Fiscal 1984	Forecast for FY 1985
Compact disks	Players	770,000 units (including 540,000 units exported)	2 million units (including 1 million units for export)
	Software	6.25 million disks	35 million to 40 million disks
		¥14 billion	(*12 million disks) (*¥30 billion)
Video disks	Players	24,000 units	500,000 to 600,000 units
	Software	--	10,000 to 15,000 disks
		¥40 billion	¥80 billion
Optical files	Systems	1,000 units	2,000 units
	Optical disks	-	-

*Initial forecast

Table 11. Player Production Plans of Principal Makers

(Makers producing 10,000 or more players monthly are listed in arbitrary order)

Maker	Present production level	Production increase plan
Sanyo Electric	300,000 units in first half of this fiscal year	400,000 units in second half of this fiscal year
Sharp Corp.	10,000 units/month	Gradually increasing depending on demand
Sony Corp.	80,000 units/month	Increasing to 140,000 units/month by this fall
Toshiba Corp.	12,000 units/month	Gradually increasing depending on demand
Nippon Gakki	25,000 units/month	Considering production at 400,000 units/year in the future
Hitachi Ltd.	15,000 units/month	Increasing to 20,000 units/month this summer
Matsushita Electric Industry	15,000 to 20,000 units/month	Increasing to 50,000 units/month or more in second half of this year

seen from the table, the makers appear quite bullish. It may be said that their morale has largely been stimulated by continued growth in compact disk player sales with export accounting for about half the total sales and also by the introduction last year by Sony Corp. of its ¥50,000-plus compact disk player D50. It is believed that the worldwide compact disk player output will exceed 10 million units in 1987. Under these circumstances, the industry's forecast for compact disk software output has largely been modified outward; the output initially forecast to increase from 6.25 million disks (worth ¥14 billion), recorded last year, to 12 million disks (worth ¥30 billion) this year is now estimated to exceed 35 million disks.

In FY 1984, a total of 240,000 video disk players were sold in Japan. The forecast for video disk player output initially put at 500,000 units for this fiscal year has also been modified to 600,000 units. The video disk software output is also expected to rise sharply to 10 million to 15 million disks this year.

In the field of optical file systems, Toshiba Corp. at present holds a market share of over 50 percent. Since it introduced the TOSFILE3200 optical file system (with a recording capacity equivalent to 60,000 pages of paper in A4 size) in 1983, its TOSFILE3200 sales have rapidly been increasing, and it now outputs more than 200 systems of the TOSFILE3200 monthly. Such optical file systems are mainly used to manage design and general drawings in the manufacturing industry. Recently, however, users in the field of administrative services, which include government and municipal offices, have been on the increase. With microfilm systems being the only direct competitor against optical file systems, the industry expects that the demand for optical file systems will continue expanding and that the total output of optical file systems will surpass 2000 systems this fiscal year. There are, however, still many problems left to be solved by the makers. Optical file systems are still expensive, being priced at over ¥10 million each, and require their users to take time in acquiring skill needed to efficiently use them. In addition, different makers are promoting different types of optical file systems manufactured according to different specifications.

Optical disk systems to be used as external memory devices for large-scale computers are still in the process of development. They will be introduced for practical use before long and are considered to have a promising future.

6. Outlook for Optoelectronics Industry

In the foregoing, the writer discussed optoelectronics technology, production methods, products, and markets focusing on the three categories of products that have been collecting attention; optical fibers, semiconductor lasers, and optical disks.

Optical fiber technology is considered to have entered the mature stage. The demand for optical fibers is expected to expand in the future, as their production cost comes down. The demand for semiconductor lasers will also increase, whereas polarization into two fields, that is, single-mode semiconductor lasers for optical communications and high-output semiconductor lasers

for civil use, is being promoted. Semiconductor lasers, however, still require further technological development for reliability enhancement to a level comparable to those of other developed electronic parts. In the field of optical disks, compact disk and video disk, audio software will replace LP records in the future, and the anticipated commercialization of rewritable optical disks will no doubt cause further demand for optical disks for use as document files and external memory devices. The future advancement of optical disk-related technology will affect the progress of studies being made to develop optoelectronic IC's.

OITDA forecasts that the optoelectronics market will grow to about ¥2 trillion by 1990 and ¥12 trillion by the year 2000 (see Figure 6). It estimates that, of the optoelectronics market in the year 2000, optoelectronic parts will account for 22 percent (¥2.6 trillion), optical communication systems 36 percent (¥4.3 trillion), and optoelectronic devices 42 percent (¥5 trillion).

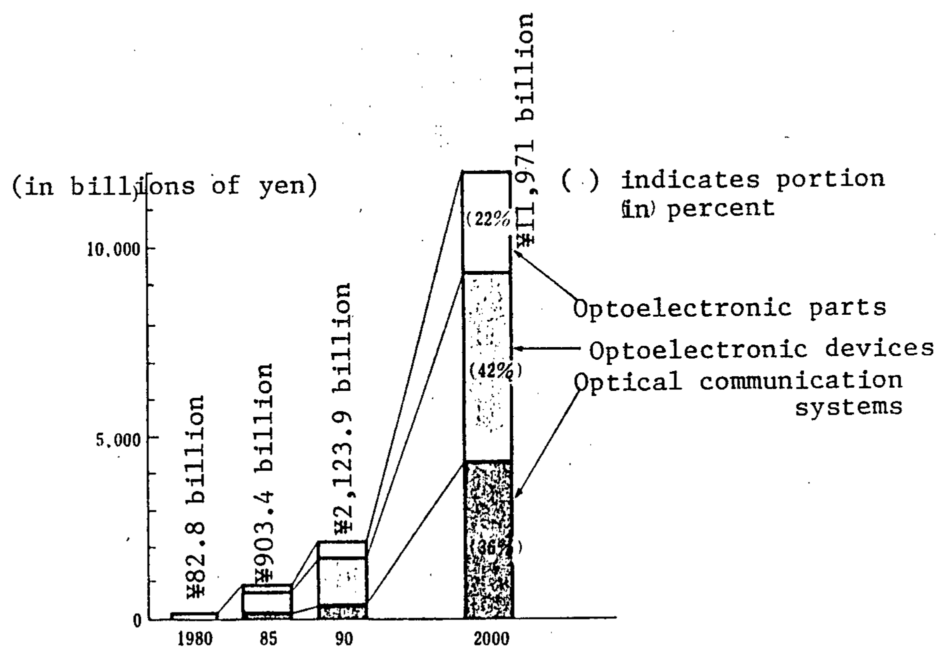

Figure 6. Transition of Optoelectronics Market Size

The optoelectronics industry will no doubt continue expanding to become a major industry, ranked next to the IC industry.

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POST-NTT OPTICAL FIBER BUSINESS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Dec 85 pp 12-15

[Excerpt] Demand Changes Little This Fiscal Year

Optical fiber has come into a leading role in information transference in the new electronic media age. However, reality is not always bright.

According to statistics of the Optoelectronic Industry and Technology Development Association, domestic production of optical fiber cables has risen smoothly. In fiscal 1982 it was about Y15 billion, in fiscal 1983, about Y39.9 billion, and in fiscal 1984, about Y45 billion. However, it is estimated that the amount in fiscal 1985 will increase by several percent, at best.

The largest single cause for this is a reduction in the amount of optical fibers supplied to NTT (Nippon Telegraph and Telephone Corp.). The amount of optical fiber cables procured by the NTT in fiscal 1982 was about Y3.2 billion, about Y25 billion in fiscal 1983, and in fiscal 1984, about Y29.6 billion. These figures show the central role played in optical fiber cable procurement by NTT.

Optical fiber cable procured by NTT has increased sharply since fiscal 1983 because construction work laying optical fibers on a route running through Japan has started. This work is a part of the INS (Information Network System) Project.

The work was started in the sector between Tokyo and Yokohama in March 1983. This will form the main artery of the digital network of the INS Project. Work between Sapporo and Asahikawa was started in February 1985. Thirty-four main cities have been connected to each other in this project, and the optical fiber running cable artery extending over 3,400 kilometers between Asahikawa and Kagoshima has been completed. Total construction cost is about Y65 billion. Optical transmission with a large capacity of 400 megabits per second has been realized. Demand for optical fiber increased sharply because of this.

Although other construction work laying optical fiber in sectors over the whole of Japan is being carried out, it is anticipated that the amount of

optical fiber cable to be procured by NTT in fiscal 1985 and in subsequent years will not be greatly increased.

The second reason for slower growth is that the use of optical fiber has not yet spread among private enterprises. Japanese optical fiber technology is top level, and reliability is evaluated to be the highest in the world. The problem lies in the price.

Optical fiber requires large research and development expenditures and investment in plants and equipment. It is roughly estimated that the amount of optical fibers to be produced by domestc manufacturers in fiscal 1984 will be at 100,000 kilometers. The amount of optical fiber to be produced annually in the United States is presently more than 600,000 kilometers. Compared with this figure, it is probably natural that Japan is behind the United States in decreasing prices through mass production. Some say that the price of optical fiber (per meter) produced domestically in Japan is 1.5 to 2 times that in the United States. Also, this expensive price is affected considerably by parts related to optical communications, such as light-emitting devices, photo detectors, connectors, branching filters, etc., which are still more expensive.

As a third reason, it is very difficult to import optical fiber from foreign countries due to the patent of Corning Glass Works in the United States. Particularly, it is extremely difficult to import optical fiber from the United States given the basic patent there of Corning Glass.

Patent of Corning Glass in the United States

There are three patents of Corning Glass, which frequently become problems. One (No 3659915) is a basic patent which is applied to the composition of almost every optical fiber presently being produced for communications systems. When fused silica core materials are subjected to a doping treatment, the refractive index of cores is higher than that of surrounding silica (clad). Optical signals are confined in the cores by the difference between the refractive indexes, and these materials are able to move forward in fibers. The remaining two patents cover optical fiber (No 3884550) and the method (No 3933454). The optical fiber contains more than 15 percent germanium, which is a component forming glass in cores. The method is used to dehydrate optical fiber preforms (glass base materials) manufactured by hydrolyzing flame.

In October 1983, Corning Glass instituted a suit against the U.S. Government for the purpose of making valid Nos 3659915 and 3884550. The suit was sanctioned by the U.S. Supreme Court. Since then, when the government has procured optical fiber from enterprises which have not obtained approval for the company's patent right, the government has had to pay compensation money to the company.

At present, Corning Glass is taking legal proceedings in the ITC (International Trade Committee) in the United States against Sumitomo Electric

Industries, which is one of the leading manufacturers in Japanese optical fiber. Sumitomo Electric is producing optical fiber using the process mentioned in patent No 3884550 and is selling optical fiber covered by patent No 3659915 in the United States.

In addition, Corning Glass has sued Sumitomo Electric for damages caused by selling the optical fiber, that is, infringing upon the patent, at a district court located in the southern part of the State of New York in the United States. Corning Glass has also requested the district court to issue an order prohibiting Japanese manufacturers from selling in the United States optical fiber infringing upon the company's patent.

The market for optical fibers in the United States will reach $2 to 3 billion in 1990. It is an attractive market for Japan. However, it is difficult for Japan to find such a market in the United States on a full scale and to export optical fiber to other countries where Corning's patent is effective, unless the problem of the patent is solved.

As mentioned, at present, there is no factor which will sharply increase the demand for optical fiber.

Market Is Stagnant

Next shown are the sales of Japanese manufacturers related to optical fiber. In Japan, silica optical fiber for communication systems are manufactured mainly by cable companies.

Sales of main Japanese manufacturers, related to optical fiber in fiscal 1984 are as follows: 1) Sumitomo Electric Industries, about Y21 billion (23.5 percent above the comparable figure for the previous fiscal year); 2) Furukawa Electric Co., about Y13.5 billion (2.3 percent rise); 3) Fujikura Cable Works, about Y14.5 billion (16 percent rise); 4) Hitachi Cable, about Y4.1 billion (17.1 percent rise); 5) Dainichi-Nippon Cable, about Y2.5 billion (25 percent rise); 6) Showa Electric Wire & Cable Co., about Y2 billion (33.3 percent rise). Sales of multi-component glass optical fiber, fiber scopes, optical communications parts, optical communications systems, etc., as well as silica optical fiber for communications are included in these figures. Also, sales of optical fiber sold as cables is included. Therefore, these figures are far from the next sales figure. Shown above, however, are the sales figures for reference. Several prestigious cable manufacturers other than the companies listed are also producing optical fiber. Multi-component glass optical fiber for communications are being produced by Nippon Sheet Glass Co. and others, and plastic fiber is being produced by Mitsubishi Rayon Co. and Asahi Chemical Industry Co.

The reason why three companies, Sumitomo Electric, Furukawa Electric, and Fujikura Cable have much larger sales than the next three firms is that the leading three have developed VAD (vapor-phase axial deposition) in collaboration with NTT and are the only three companies approved to deliver

optical fiber to NTT. VAD is a method of manufacturing preforms, which is peculiar to Japan.

Anticipated sales of optical fiber to be manufactured by the six main companies in fiscal 1985 are: 1) Sumitomo Electric, Y23 billion; 2) Furukawa Electric, Y13.5 billion; 3) Fujikura Cable, Y17 billion; 4) Hitachi Cable, Y5.5 billion; 5) Dainichi-Nippon Cable, Y4 billion; 6) Showa Electric Wire & Cable, Y3 billion.

The growth rate has slowed, because the market scale has increased. However, the optical fiber market, in which it was said that sales would reach Y200 billion in 1990, has already started to stabilize. This has considerably irritated optical fiber manufacturers.

One can wonder how each manufacturer handles this reality.

In conclusion, the manufacturers cannot overturn the ceiling set for optical fiber procurement by NTT.

With the route running through Japan just now being completed as the largest INS Project, the amount of optical fiber procured by the NTT has been settled. Although only three companies were approved to deliver optical fiber to NTT until completion, it has been decided that NTT will now open its doors to other optical fiber manufacturers, as well as the three companies. However, they do not expect the delivery of optical fiber to NTT at present, with the route running through Japan just now concluding.

To What Extent Can Subscriber's System Be Expected?

When NTT procures a large amount of optical fiber in the future, the subscriber transmission line connected between the telephone station and households, or between the telephone station and enterprises, will be optically connected. When optical fiber is introduced into the subscriber's system, a huge market with an annual production quantity of 1.3 million kilometers will be realized.

With regard to the application of optical fiber to general subscribers, research on the following is being conducted: 1) miniaturization of optical transmitters, 2) rise in economic efficiency of optical transmitters, 3) reduction in cost of optical fiber cables, 4) use of multi-core optical fiber cables, 5) technology on hardware such as wave synthesizers, branching filters, etc., for wavelength multiplex transmission systems. In 1982, field tests on optical fiber subscriber's transmission systems were performed in the Mitaka area in Tokyo, and in 1984, operational tests were started in the Kasumigaseki and Marunouchi areas in Tokyo. Also, a subscriber's optical fiber cable transmission system was adopted in the image, high-speed digital, and other services at the Science and Technology Exposition held in Tsukuba.

As mentioned, the introduction of optical fiber into the subscriber's system is being studied, but the plan has not yet been applied. Although it is said

that progress in the INS Project will be quickened by the fact that NTT has come under private management, it will probably be at least 5 to 10 years before optical fiber cables are spread throughout the subscriber's system. In the worst (uneconomical) case, there is a possibility of conventional coaxial cables being used in the subscriber's system.

One cannot expect that demand for optical fiber to NTT will increase. Instead, NCC (New Common Carrier) has introduced optical fiber cables together with liberalization of information communications. Japan Telecom Co., whose main investor is the JNR (Japanese National Railways) is planning to lay optical fiber cables in areas along the Shinkansen Lines. Japan High-Speed Communications Co. is planning to do this in areas along the Tomei and Meishin Expressways.

Demand for the third trans-Pacific optical fiber cables scheduled to be completed in 1988 is expected. According to the plan, a direct communication route between Japan and Hawaii, and communication routes among Japan, Hawaii, and Guam have been established by KDD (Kokusai Denshin Denwa Co.). These cables are scheduled to be used by Asian countries along the route between Japan and Guam as well as the route between Japan and North America.

In the future, the amount of such cable to be delivered for this plan will gradually increase, and this increase will, to some extent, cover the stagnant sales of optical fiber to NTT, the largest customer. However, there is little possibility of the market for optical fiber exploding.

Still Expensive

Given all this, optical fiber manufacturers will start buckling down to the increase in private demand for optical fiber and overseas expansion of optical fiber as urgent subjects.

These manufacturers are making utmost efforts to reduce production costs with the aim of full-scale spread of optical fiber at the private level. With regard to investment in optical fiber, manufacturers place great importance on the rationalization of production rather than on increases in production capacity. Research on rationalization, shown below, is being conducted in accordance with increasing yields: 1) use of large preforms; 2) reduction in probability of fiber drawing breakage due to rise in cleanliness; 3) reduction in production costs due to reduction in terminal scale; 4) employment of large facilities and simplification of each process with the aim of doubling glass producing speed.

The present price per meter of silica optical fiber depends on the kind of cable, but it is at the level of hundreds of yen. The purpose of manufacturers is to reduce this figure to the level of tens of yen. These manufacturers are planning to reduce costs annually by about 20 percent.

The manufacturers have also been developing products to which optical fibers are applied, such as power cable, aerial wire, and others. They have been

producing optical fiber cable with special specifications which can be used in special environments, such as at high temperatures, cryogenic temperatures, high pressure, radiation, etc. In addition, they have been developing optical fiber scopes and various sensors employing optical fiber as well as communication cables, and have been enthusiastically expanding optical fiber products.

It is said that Japan will advance the private use of optical fiber to first in the world, because Japanese manufacturers are making every effort to introduce optical LAN (local area network) into their offices and factories. However, it seems that it will take considerable time to raise the economic efficiency of optical communications systems and to introduce these systems successively into enterprises.

Each manufacturer aims at making inroads into foreign markets as well as increasing private demand for optical fiber.

Sumitomo Electric has boldly challenged the patent of Corning Glass, which constitutes a large barrier to Japanese inroads into foreign markets. As previously mentioned, Corning Glass has brought a suit against Sumitomo in the district court because of patent infringement. In opposition to this, Sumitomo has conversely sued Corning Glass because of a nullity of the patent, and has simultaneously started producing optical fiber in the field of the United States.

Inroads Into United States in Preparation for Friction

Sumitomo Electric has established a research body, SERT (Sumitomo Electric Research Triangle) in the Research Triangle Park, North Carolina, and has requested SERT to construct a research institute. An up-to-date plant for manufacturing fluoric dope optical fiber has been completed in the research institute, and operations were started, at an annual production scale of 30,000 to 50,000 kilometers, in February. In addition, SERT is reinforcing the production capacity, and is studying the work of manufacturing parts related to optical fiber.

SERT has established a company for manufacturing optical fiber using VAD, under joint management with Australian cable manufacturers, Optix Australia Co. and Pirelli-Ericsson Co. The company will start producing such optical fiber in the field this autumn. A single mode optical fiber cable is scheduled to be laid as a trunk line extending over about 1,000 kilometers in Australia between Sydney and Melbourne, and a plan for laying optical communications networks throughout the whole country will be promoted. SERT will positively participate in the plan.

In addition, Sumitomo Electric has offered technology on VAD, as well as many other technologies, to Jaihan Electric Wire Co. in South Korea, Pirelli General plc in England, and Wacker Chemie GmbH in West Germany, and has discussed overseas production projects.

On the other hand, Corning Glass has established optical fiber manufacturing companies throughout the world under joint management with respective enterprises in their fields, and has organized the "Corning alliance." The overseas strategy of Sumitomo Electric has directly challenged the Corning alliance to a business competition. Sumitomo Electric wants to show itself as an optical fiber manufacturer which stands third after U.S. AT&T Technology and Corning Glass. However, this strategy has extremely high risks.

While Sumitomo Electric has directly confronted Corning Glass, Fujikura Cable has gradually attacked the U.S. optical fiber market from the rear. Fujikura has joined hands in manufacturing OPGW (optical fiber ground wire) with Alcoa, the largest aluminum refining manufacturer in the United States. Aluminum steel wire is stretched as lightning rods together with high-voltage cables among pylons. OPGW is a product manufactured by passing optical fiber into aluminum steel wire, and can be used for information communication systems. However, Fujikura has a policy to procure core materials for optical fiber from other manufacturers in the United States, and has avoided all-out competition with Corning Glass.

Following these two companies, other Japanese manufacturers have also started feasibility studies for the purpose of producing optical fiber in foreign countries.

It appears that Furukawa Electric is presently negotiating enthusiastically with an enterprise in the United States to establish a company to manufacture optical fiber under joint management. A subsidiary company for manufacturing communication cables has been established in Thailand under joint investment of Yazaki Corp. and Mitsubishi Corp. Furukawa is also planning to produce optical fiber, and is presently making an application for producing it to the Investment Agency in Thailand.

Conversely, it appears that Dainichi-Nippon Cable has received inquiries for producing optical fiber in the United States under joint management and cooperation with several U.S. optical fiber manufacturers. Dainichi shows much enthusiasm for these inquiries. The company has already established a firm to sell optical fiber scopes in the United States. Also, Dainichi-Nippon has individually developed the MRT (modified rod-in tube) method of manufacturing optical fiber. Optical fiber manufactured using this method is excellent in radiation resistance, and has a great advantage in the U.S. optical fiber market because the method probably does not infringe upon the patent of Corning Glass.

Showa Electric Wire and Cable has also started buckling down to export multi-component gas optical fiber not related to the patent problem.

Although the inroads of Japanese optical fiber manufacturers into foreign markets have thus far been checked by the Corning patent, it seems that these manufacturers have now started confronting foreign markets. Particularly, they are looking at the U.S. market, where it is anticipated that the scale will reach $3 billion in 1990.

The Near Future Will See a Do-Or-Die Situation

The United States has two giants, AT&T Technology and Corning Glass which account for 40 to 45 percent of the market. Particularly, Corning Glass has been giving a good deal of encouragement to reinforcing its production capacity, and will increase annual production to more than 1 million kilometers in 1986. Corning will not give the Japanese manufacturers any chance of catching up. The Japanese firms have several difficult problems in foreign markets.

For the time being, no decisive measure will sharply expand the optical fiber market in Japan.

Ultimately, the point is how to raise profitability of optical fiber until the market is expanded by introducing optical fiber cables into subscriber's systems in the INS Project.

Siecore Co., Ltd., a cable manufacturer, has been established under joint management of Corning Glass and Siemens AG in West Germany. To make matters worse, this company aims to sell optical fiber cables in the Japanese market with Sony Corp. as its Japanese agency, in anticipation of increases in demand for optical fiber, caused by the INS Project. That is, foreign manufacturers are also challenging in Japan. The removal of duties on optical fiber will encourage such movements by foreign manufacturers.

Optical fiber is one of the truly great inventions of the 20th century. Although Japan is proud of its top-ranking world technology for manufacturing optical fiber, it can probably be said that many difficulties await Japan until the Japanese optical fiber business truly becomes fruitful.

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NEW METALS, CERAMICS, PLASTICS USED IN VARIETY OF PRODUCTS

Tokyo NIKKO MATERIALS in Japanese Dec 85 pp 28-32

[Text] Metals

Domestic Production of High-Output Laser Mirror Using High-Purity Molybdenum

Nippon Mining Co. has succeeded in domestically producing a high-quality molybdenum mirror with a purity of at least 99.999 percent and a maximum diameter of 5 inches for the first time, and has started supplying it on a trial basis. This high-quality molybdenum mirror is used for such high-output lasers as CO_2 lasers, etc.

At present, gold-coated copper mirrors are being used for high-output lasers, but these have two problems. One is the low reflectance caused by flaws and discoloration on the surface of these mirrors; the other is the unstable beam caused by thermal strain. The molybdenum mirror corrects these two defects, but it had not been produced domestically, because it is difficult to work a molybdenum mirror.

Nippon Mining has successfully developed a polishing technology using alumina particles, which is based on the molybdenum target for gate electrode materials of VLSI's (very large-scale integrated circuits). This has opened the way for domestic production of molybdenum mirrors. Because of this, Japan has reached the highest level of production of these mirrors in the world. The surface roughness among crystal particles is less than 60 angstroms, the surface roughness within crystal particles is less than 5 angstroms, the plasma occurrence threshold value is 94 joules per square centimeter, and the repeat irradiation life span is 1,400 times (at 60 joules per square centimeter).

Sandvik Puts Cermet Chips and Two Other Units on the Japanese Market in a Big Way

Sandvik Co., a cement tool manufacturer in Sweden, has put on the Japanese market in a big way, the cermet chip which is a kind of cement tool material, a total tool control system called "Core Cut," and an automatic rotary tool changer.

The cermet chip is a tool material accounting for 20 percent of the Japanese cement tool market. Demand for it has increased sharply because it has a long life span and can be cut at high speed and with high accuracy. Up to now, Sandvik has only put samples of machine tools on the Japanese market. Core Cut is a personal computer for setting cutting conditions, controlling tools, and calculating costs. It also outputs the optimum cutting conditions and tool costs at real time. It is expected that Core Cut will be very effective for promoting the numerical control of machine tools and the adoption of FMS's (flexible manufacturing systems).

In addition, the automatic rotary tool changer is designed for wide use for lathes, drilling machines, and MC's (machining centers). Sandvik plans to make every effort to promote the sales of these tool changers.

AE System Tool Damage Detector With Microcomputer Control System

IHI (Ishikawajima-Harima Heavy Industries Co.) has put an AE (acoustic emission) system tool damage detector to practical use, and has started selling it. This detector is designed to promptly detect tool damage caused during operation of NC (numerical control) machine tools by using the acoustic pulse signals generated at the time solids are damaged.

The detector has been developed using a phenomenon where, when tools are damaged, AE signals emanating during steady-state cutting work are sharply increased manyfold. Moreover, the detector employs a microcomputer control system, and an AE detection device incorporated in the detector possesses functions for automatically setting tool damage detecting conditions and for recording data on AE signals. In addition, measures have been taken to prevent noise generated at any time other than during operation of NC machine tools. The detector is compact, and can be used for most NC machine tools when it is simply modified or its program corrected.

The detector is available in two types, Type-T (tool corresponding type) and Type-P (process corresponding type), to better cover AE signal detecting conditions.

Portable Heater Using Sodium Acetate Base Latent Heat Accumulating Material

Matsushita Electric Industrial Co. has a portable heater called the "Heat Accumulating System Hot Pack" on the market. Sodium acetate base latent heat accumulating material is used in the heater.

The latent heat accumulating material used in this hot pack has just been developed by the company in collaboration with Matsushita Jusetsu Equipment Co. It has the following features: 1) The material accumulates heat while it melts, from a solid to a liquid state, at a melting point of 58 degrees centigrade. Subsequently, it maintains the melting point without being influenced by room temperatures, and dissipates heat while it slowly changes from a liquid to a solid. 2) The amount of accumulated latent heat is 60 calories per gram, which is 60 times that of water at the melting point

mentioned above. 3) The amount of accumulated latent heat up to temperatures of 40 to 60 degrees centigrade, is 3.4 times that of the same weight of water. 4) The material can accumulate and dissipate heat repeatedly and with stability because it containes LiF (lithium fluoride), specially treated as a crystal nucleus.

This new hot pack is manufactured by packing a substance with heat insulating material and a waterproof bag. The substance is made by layering a heater and a product unified by sealing the heat accumulating material with aluminum foil. The hot pack has the following features: 1) short electro-conductivity (40 to 80 minutes); 2) long heating (3 to 6 hours); 3) can be used repeatedly; 4) heat can be accumulated in the hot pack wherever an AC socket-outlet of 100 volts exists; 5) it is thin, and has a large exothermic area; prices are Y9,000 for the 3-hour type, Y11,000 for the 6-hour type, and Y20,000 for the 6-hour wide type.

Clad Titanium Steel Put to Practical Use, Used in Chemical Reactions, Tankers, etc.

Sumitomo Metal Industries and Nippon Steel Works have succeeded in cladding titanium, and have started putting it to practical use.

Titanium has been used in various fields because it is lightweight and has high corrosion resistance. However, its demand has been limited because it is expensive. For this reason, Sumitomo Metal and Nippon Steel have thought to ensure corrosion resistance and rust prevention of titanium, while reducing the amount of titanium used, by attaching titanium to steel plates.

It is difficult to clad titanium, because it is liable to be oxidized and an oxide film forms quickly on the surface of the titanium in the atmosphere. The practical cladding method developed by these two companies is that titanium is hot-rolled and clad on base steel plate.

The practical clad plate made by Nippon Steel measures 40 millimeters in titanium plate thickness and 320 centimeters in width, and that made by Sumitomo Metal measures 6 to 80 millimeters in thickness and 230 centimeters, at most, in width. Sumitomo is planning to clad titanium steel plates up to a width of 450 centimeters.

Ceramics

Yuasa Battery and NGK Spark Plug Establish New Company to Commercialize Ceramic Batteries

Yuasa Battery Co. and NGK Spark Plug Co. have jointly established a new company called "Ceramic Battery Co." to develop ceramics (beta-alumina solid electrolyte, etc.) with an alkali ion conductivity, conduct research and development on a sodium-sulfur battery to be manufactured using these ceramics, and to put the battery on the market.

Both companies have conducted research on new battery power storage systems since they established a beta ceramic joint research institute on consignment from NEDO (New Energy Development Organization) based on the Moonlight Project (research and development on energy conservation technology) of the Agency of Industrial Science and Technology of MITI in 1983. As a result, 86 percent energy efficiency has been attained in 1-kilowatt class sodium-sulfur batteries. However, the companies have currently closed the research institute because development of 10-kilowatt class batteries has been carried out on schedule. They has established the new company in preparation for a demonstration plant which will be constructed by 1990. Energy efficiency will be further enhanced. Also, the demonstration plant will operate using 1,000-kilowatt class batteries.

In the future, the new company will quickly carry out NEDO's development work, and is planning to develop an electric vehicle battery, etc., using the above batteries. The address of the new company is: Central Research Institute, Yuasa Battery Co., Josai-cho 6, Takagi-shi, Osaka-fu. Capital is Y50 million. Teruhisa Yuasa, vice president of Yuasa Battery Co., has been chosen as president of the new company.

High-Hardness, High-Adhesive Ceramic Base Steel Frame Fireproof Material

Kajima Corp. has developed a ceramic base steel fireproof material called "Cerataika" in collaboration with Shikoku Chemical Corp. and Nippon Valqua Industries and has put it on the market.

Generally, materials made by adding cement to rock wool have been used as gunning fireproof materials for steel frames, but there have been problems in areas such as specific gravity, adhesion, and surface hardness.

As shown below, defects of rock wool cement base fireproof materials have been corrected using new fireproof materials composed of silica alumina. 1) Both strength and hardness are high, and no dust occurs. 2) There is neither delamination nor desorption, and there is no need to provide reinforcing metal fittings, because of high adhesive force. 3) There is no need to apply rust preventive paint to the new fireproof materials because of high rust preventive properties. 4) The process can be shortened because of quick hardening speed. With regard to color tone, these new materials can be finished brightly in white. In addition, the materials generated little dust during work thanks to a wet processing method, and there is no occurrence of mold.

The price is Y3,500 per square meter in the case of 1-hour fireproof materials with a thickness of 20 millimeters.

Porous Spherical Ceramics for Purifying Water, Based on Biotechnology

Onoda Cement Co. and Tomei Enterprise Corp. have jointly developed a porous spherical ceramic called "CB Filter Medium" for purifying water. It is a bio-oxidization method based on biotechnolgy, and sales have started well.

The CB filter medium is a ceramic burnt at a high temperature. It consists mainly of aluminum silicate, and is porous enough for microorganisms to easily attach to its surface and live thereon. Thanks to this feature, the CB filter medium can be used for both aerobic and anaerobic bacterium, and water close to natural can be kept.

There are two types of purifying systems. The first is a fixed filter bed, the other is a fluidized filter bed. At present, the fixed filter bed will be put on the market, and the fluidized filter bed will be developed so it can be put on the market within the year.

Ceramic Base Self-Leveling Underfloor Material

Ube Industries has developed a ceramic base self-leveling underfloor material known as "Quick Ceramic Flow" using technologies introduced from BPA Co. in Sweden, and has placed it on the market. Quick Ceramic Flow has excellent self-leveling characteristics, and has a quick hardening speed.

Two types of gypsum base and cement base self-leveling underfloor materials have been used up to now, but they have had the following two problems. 1) It is necessary to take rust preventive measures, because gypsum base self-leveling underfloor material has low water resistance. 2) Cracking is liable to occur on the surface of cement base self-leveling underfloor material.

Quick Ceramic Flow has been developed in order to solve these problems. It can be worked merely by placing pipes, because of its excellent self-leveling features. In addition, it has high heat-retaining and high sound-insulating properties.

Ube has decided to take a production and shipping system with a monthly capacity of 1,000 tons in the Kanto and Kansai Districts.

High Heat-Resistant Casting Ceramic Foam Filter

Bridgestone Tire Co. has develoepd a casting ceramic foam filter with the brand name "MF Series" which can be used in molten metal up to a temperature of 1,800 degrees centigrade, and has put it on the market.

When iron, particularly, ductile iron is cast, slag and ductile come into the cast iron and exert a bad influence on the quality and workability of the casting. Therefore, various measures have been taken, up to now, to remove such slag and ductile.

The MF Series has excellent filter effects, because it has a three-dimensional net structure different from that of conventional strainers with straight holes. Also, the rejection rate has been lowered, the casting yield rate has been enhanced, the quality of casting has been stabilized, and the cost of inoculant is one-third that of inoculant which has been used up to now. This is done by rectifying the molten metal, simplifying the casting plan, and enhancing the immold inoculating function.

Fine Ceramic Base Heat Insulating Boards Which Can Be Used Normally At a Temperature of 1,700 Degrees Centigrade

Three companies, Tateho Chemical Industries Co., Taiyo Chemical Co., and Motoyama Co. have jointly established a technology for manufacturing fine ceramic base heat-insulating boards. They will place these boards on the market with the brand name "TAF Board." TAF Board can be used normally and continuously at a high temperature of 1,700 degrees centigrade by adjusting fibrous density, and so forth. This new product is made of ceramic fiber (alumina ratio : 95 percent) consisting of alumina and silica.

At present, kiln materials made of ceramic fiber are being manufactured in Japan. These kiln materials can withstand a temperature of around 1,400 degrees centigrade and sometimes up to 1,600 degrees centigrade. Tateho Chemical expects that the above technology will enable one to apply the new board to the lining heat-insulating materials for kilns, gaskets, quick-speed high-temperature heating fireproof materials, etc.

Plastics

Optical Sheet Materials Made of Modified PVC, Which Can Cut Off Optical Energy Emitted From Specific Wavelength Regions

Tsutsunaka Plastic Industry Co. has established a technology for manufacturing optical sheet materials made of modified PVC (polyvinyl chloride), which can cut Off optical energy emitted from specific wavelength regions. At first, Tsutsunaka will put these materials on the market under the name "Technalight IR Series." There are two kinds in the Technalight IR Series. One is for a cut-off wavelength of 700 nautical miles or less, and the other for that of 800 nautical miles or less.

Special organic compounds based on modified PVC are added to these optical sheet materials. Such materials are manufactured in the form of a sheet on the basis of precise control of temperatures. The materials are devised so they can convert optical energy emitted from specific wavelength regions into heat, and irregularly reflect and absorb the light.

The IR Series is designed so a filter incorporated in it can cut off more than 90 percent of the light with a wavelength of less than 700 to 800 nautical miles. Also, this filter can prevent misoperations caused by noise generated from equipment employing an infrared remote-control unit. This series conforms to the most difficult grade (94, VO) stipulated by the UL standard, and is excellent in resistance to humidity, weather, and chemicals. In addition, it can be readily molded.

Tsutsunaka is planning to put the series on the market for remote-control units, crime prevention equipment, infrared cameras, and factories for manufacturing sensitized materials.

Sintered Porous Body of Thermosetting Resin Put to Practical Use

Spacy Chemical Co. has developed a sintered porous body based on phenol base resin called "Spacy SAMS-81," and has started receiving orders for its moldings.

Up to now, it has been difficult to put a sintered porous body based on thermosetting resin to practical use, because the molding and setting of resin are promoted simultaneously. Spacy has currently succeeded in controlling the viscosity of thermosetting resin. As a result, it is able to sinter, mold, and set the thermoplastic resin in the same way as a porous body.

This thermosetting resin porous body has excellent resistance to heat (180 degrees centigrade), chemicals, and oils, because it has a three-dimensional crosslinked structure. It is also breathable, because it has continuous voids. In addition, high-filtering accuracy can be obtained, because the diameter of the voids is unified by 5 mu. The bending strength is 50 kilograms per square centimeter, and the compressive strength is 40 kilograms per square centimeter. It is anticipated that the thermosetting resin body will be used for filters for working oil and fuel systems, accurate filters for solvents, electric diaphragms, catalyst supporters, etc.

The price is Y10,000 to 15,000 per liter, about one-tenth that of ceramic porous bodies.

Kyowa Gas Chemical Industries Co. developed a VDT (visual display terminal) filter, and will commercialize it in the near future. This filter possesses a function for shielding electromagnetic waves.

Kyowa has commercialized VDT filters which can cut off radiation, but the new filter can restrain electromagnetic waves as well. MMA (methyl methacrylate) plates containing lead are manufactured by copolymerizing organic lead compounds with MMA which are excellent as barriers to radiation. The development of the new filter has successfully put synthetic fiber plated with nickel in such MMA plates.

It is said that the performance for shielding electromagnetic waves is 30 decibels or less, which clears the value stipulated by the FCC (Federal Communications Commission) in the United States.

ICI Japan Imports Fron 113 and Special Grade of 1.1.1.-Trichloroethane, Puts Them on the Market

ICI Japan has started importing "Arcton (Fron 113)" and "Propacron (special grade of 1.1.1.-trichloroethane)," and has placed them on the market.

ICI Japan has imported four kinds of chlorinated solvents, and has put them on the market since 1982. The amount of chlorinated solvents sold during this period has increased favorably. At present, the market share is nearing 5 percent. On this basis, ICI has decided to import Arcton and Propacron, and

to put them on the market. Arcton is in great demand, mainly by electronics users. Propacron, employing an in-line cleaning method, is effective as a flux detergent or a resist ink detergent. ICI will import these products and sell them aiming at a market share of 10 percent, which it wants to obtain within several years.

Electronic Parts Sealed, Thermoplastic Resin Molded Using an Injection Molding Method

Japan Steel Works has succeeded in making practical a molding process for sealing electronic parts. This process employs an injection molding method.

A ceramic sealing method and a resin sealing method are ways of protecting electronic parts, such as IC's (integrated circuit), capacitors, etc., from water and dust. However, the main method presently is a transfer molding method, employing a thermosetting epoxy resin. In this method, thermosetting epoxy resin is tableted and preheated to about 80 degrees centigrade, is embedded in a mold with set elements, and heated and sealed up to 170 to 180 degrees centigrade.

This method has two difficulties. 1) Moldings can be mass-produced, but in order to obtain these moldings, it is necessary to heat materials for about 3 minutes to harden them. 2) The manufacturing process cannot be automated, and the yield rate of materials is low because the work of inserting tablets into the mold must be carried out manually.

The injection molding method currently developed by Japan Steel is called the "low pressure injection molding method." In it, the filling behavior of melt resin flowing in mold cavities is simulated and analyzed using computers, and energy is optimized with neither deformation nor breakage of IC's gold wires. This method enables one to mold thermoplastic resin, continue the process, automate the work, and increase the speed of molding cycles.

The pressure in the mold of the injection molding machine is a maximum of 150 kilograms per square centimeter, which is one-tenth that of conventional injection molding machines. The pressure imposed on the elements of electronic parts can be minimized by accurately controlling the new injection molding machine.

Development of Nut and Bolt Made of GFRP

Asahi Chemical Industry Co. has developed a nut and bolt made of GFRP (glass fiber reinforced plastics), to be used for chemical plants and transformers, and has placed them on the market on a trial basis.

Compared with metallic elements, the resin bolt has high resistance to corrosion. In addition, it is lightweight, and has excellent electrical insulation properties. Nuts and bolts made of PVC, or similar materials, have been commercialized before, but their use for structures, etc., has been limited, because of low strength.

The method of manufacturing the new nut and bolt is as follows: Epoxy resin and glass fiber are mixed, the mixture is treated using an extruder, and the treated mixture is threaded. The strength of the new nut and bolt is much greater than those made of PVC. Asahi estimates that the new nut and bolt will be widely used for assembling underwater buried objects, chemical plants, pole transformers, etc.

High-Performance Thermoplastic Elastomer Is Produced and Put On the Market

Nippon Zeon Co. has developed a high-performance thermoplastic elastomer, has started manufacturing it, and has put it on the market as "ELASTAR."

Although the thermoplastic elastomer has a rubbery elasticity, it can be worked in areas such as extrusion, injection-molding, blow-molding, etc., in the same way as thermoplastics. This material is used increasingly in many fields, including automobiles. At present, styrene base, olefine base, urethane base, and PVC base thermoplastic elastomers are on the market as higher-performance thermoplastic elastomers, easier to use. ELASTAR is a nitrile base elastomer. The method of manufacturing this elastomer is as follows: a substance made by modifying an NBR (acrylonitrile-butadiene rubber) base material and a substance made by modifying synthetic resin, are compounded, and an ion crosslinking agent is added to the compound. ELASTAR is excellent in weather resistance, chemical resistance, hardness selectivity, and colorability as well as oil (particularly, fuel oil) resistance and shape-retentivity at high temperatures (when pressure is not imposed, the temperature is 200 degrees centigrade, and when imposed, 120 degrees centigrade). Unlike rubber, ELASTAR does not require vulcanization. Therefore, it is possible to conserve energy and reproduce scraps.

This elastomer can be variously used for automobile parts, wire coating, hoses, rubber magnets, building materials, rollers, belts, etc.

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SHAPE MEMORY ALLOY READY FOR APPLICATION PHASE

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[Article by Sakae Yoshida, MITI Headquarters, Non-ferrous Metal Section subtitled, "Industrial Activity Inducement Technology Development Assistance Program"]

[Text] Research regarding shape memory retention alloy technology was initiated in 1983 as an aspect of the Industrial Activity Inducement Technology Development Assistance Program under the auspices of the Shape Memory Retention Alloy Technology Research Union. Having tallied many accomplishments, the said project was officially completed in March 1986.

The Industrial Activity Inducement Technology Development Assistance Program was established with a view to sparking life into the seriously stagnating basic materials industry in 1982. As a project theme directed toward the non-ferrous metal industry, "Shape Memory Retention Alloy" was chosen. The Research Union was composed of six firms with non-ferrous metal firms forming its core. Furukawa Electric Co., Ltd. has acted in an executive capacity and the six firms have pursued research under a cooperative format.

Shape memory retention alloy is a breakthrough material which remembers its own shape by means of martensite transformation that some metal crystal structures go through. (It is a phenomenon of crystalline structure transformation due to temperature.) It can be regarded as an induction agent for many of the current new materials. The fact that a certain type of metal has a shape memory retention capability was discovered in the sixties at the U.S. Naval Research Laboratory. It was used by the U.S. Navy for jet fighter plane's pipe connector. However, its commercial application was nonexistent. Against this backdrop, the six Japanese firms (Furukawa Electric, Mitsubishi Metal, Tohoku Metal Industry, Sumitomo Specialty Metal, Daido Specialty Steel and Dowa Mining) that were engaged in shape memory retention alloy research formed the Shape Memory Retention Alloy Research Union.

In the 3-Year Plan established in 1983, the union sought to improve nickel-titanium alloy and copper alloy's reliability as its chief application research goal. This involved an increased precision regarding the shape transformation temperature and improved reusability capability. These project goals in turn involved a wide range of research--from liquefaction such alloy design technologies as casting technology for precision control of alloy formation to

establishment of appropriate memory heat treatment conditions, and examination of appropriate processing technologies, etc., and processing/evaluation technologies. Moreover, the shape memory retention alloy must have properties that function as independent elements. A compilation of usage manual, too, was examined.

In implementing the research, the six firms separated into a nickel-titanium group and a copper group, each comprised of three firms. For the nickel-titanium project, research into undirectional (low temperature--high temperature transformation only) and dual directional (low temperature--high temperature as well as high temperature--low temperature transformation) modes were sought. Special manufacturing technology (a method not dependent on liquefaction/casting formula) was also attempted.

For the copper alloy project, three types of alloys based on copper were studied. For both alloy types, in order to insure their reliability, the immediate objective of ±2.5°C temperature precision for nickel-titanium and ±5°C for copper was established. In terms of recycling span, the nickel-titanium project's objective was a million times and the copper project's goal, 100,000 times.

Having completed 3 years of research, the results indicate a number of major advances in both nickel-titanium and copper basic technologies.

That is to say, for nickel-titanium, a liquefaction/casting with transformation temperature within ±2.5°C range has been established. A liquefaction technique for preventing intrusion of impurities has been established also. This is particularly significant for an element that uses the shape memory retention alloy which is expected to function as a temperature sensor. In addition, in order to improve the recycling capability of the alloy, liquefaction/casting, processing and memory/heat treatment techniques were improved. Having clarified the materials' origin and their recycling capability, the initial goal of developing an element with a million times repeat-use capability was achieved. With regard to improving the mechanical, operational features, a variety of plate crystal element, coil crystal element design production was accomplished. The relationship between a given element's origin and load, operational stroke was grasped and the element's design standard, established. At the same time, with regard to the dual directional element, an attempt was made to establish a technology to improve the low temperature output. Significant advancement was made in upgrading its capability as a machinery part. Moreover, a precision casting technique was developed to enable low cost manufacture of complex configurations.

Meanwhile in the copper alloy category, the relationship between various alloy elements and transformation temperature was researched and the effect of heat treatment and processing conditions upon the transformation temperature was investigated. Through dispersion of special elements and development of segregation prevention technology and so on, there is a good prospect that the transformation temperature can be "controlled" within the original goal of ±5°C range. With regard to improving the recycling capability, the additive elements necessary to effect it was discovered and a basic material with an appropriate temperature/displacement/load curve was obtained. The attainment of the targeted

repeat use capability of 100,000 times is within reach. Also, information regarding the effect of various kinds of heat treatment technology upon the memory feature and the recycling feature has been obtained.

On the whole, although it was unfortunate that the originally scheduled applied parts design and manufacture has to be shelved because of budgetary restrictions, many useful basic technologies to enable this totally new alloy to reach the practical application stage were developed and various testing implements for manufacture and evaluation were obtained. In view of the terse (3 years) project time frame and the limited budget, its accomplishments were major. The patent applications for two research result items have been filed and six additional applications are in the preparatory stage of patent application. The patent status report regarding the shape memory retention alloy compiled by the Research Union as its autonomous research was very well received by those interested in the project. The Research Union is planning to publish data accumulation of 3 years at a symposium/reporting conference.

In the above enumerated manner the shape memory retention alloy research has been conducted for 3 years and its result has already been commercially demonstrated in a new model brassiere that a women's foundation manufacturer has begun marketing this April. In order to prevent a brassiere from losing its shape, the shape memory retention alloy is used. Restoration is dependent upon the wearer's body temperature. The brassiere wearer is thereby liberated from the concern over a steel wire frame losing its shape during washing. Perhaps due to the nickel-titanium alloy's softness, this brassiere model was sold out very shortly after it went on the market. It must have been a surprise to the researchers to have this new alloy with a shape memory retention feature used in a women's underwear. It is reported that this particular foundation manufacturer is planning to use the said alloy for girdle construction as well. It is indeed an "enviable" new material.

This breakthrough alloy is being considered for use beyond meeting the ladies' needs, in the hard hat fields as well--in automotive parts, home electric appliance, fire alarm industries, and so on. When the state assistance program is finished, it is hoped that the entrepreneurial efforts of the private sector will take over. Approaches from undreamt of industries are likely in application/use of this alloy. Several firms are about to launch their practical utilization stage. It is hoped that this new alloy will be given a legitimate "citizenship" resulting from the cooperation of users and manufacturers.

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- END -